SCIENCE INSTRUMENT AIRWORTHINESS AND CERTIFICATION PROCEDURES MANUAL

Appendix 501-III

Cryogen Venting Analysis

1 Assumptions:

1) Cabin Volume SOFIA 747 sp 30,600 ft^3 (Debrecht, Resy)

2) OSHA standards requre oxygen percentage in cabin ≥ 19.5%. In other words, cabin air must be maintained at 19.5% or more of cabin volume. Standard cabin air is held at 21% oxygen. "Occupational Safety and Health Standards for General Industry" (29 CFR part 1910)

3) Flight time used for standard operations analysis is 8 hours.

4) Fresh oxygen rate for this particular 747 is estimated to be
5,4 00 cubic feet per minute (SEC)

5) 1 liter of liquid helium expands to 26 ft^3 of gaseous helium (TBC)

6) 1 liter of liquid nitrogen expands to 25 ft^3 of gaseous nitrogen (TBC)

1.1 Standard Operations Analysis

A standard SOFIA science instrument cryostat that will fly on SOFIA will use a liquid cryogen to cool detectors down to acceptable levels for increased sensitivity to infrared radiation. The cryogens that will be used are liquid helium (LHe) at 4.2 K and liquid nitrogen (LN2) at 77 K. Boil off is caused by heat loads imparted to the cryogen reservoir from several different sources. These are heat loads from the electrical power that runs the detectors and the mechanical support system that houses cooled optics, detectors and filter wheels etc. The loads on the system determine how fast cryogens will boil off in the standard operating configuration.

Using a large dewar holding 35 liters of helium with a four day hold time and 35 liters of nitrogen with an eight day hold time, the following equations determine the boil off rate into the cabin during a standard 8 hour flight, and the resultant impact on oxygen.

35 liters helium/4 days/24 hours/day = 0.36 liters/hours
35 liters nitrogen/ 8 days/24 hours/day = 0.18 liters/hour

8 hour flight will boil off .36 * 8 = 2.9 liters of LHe
.18 * 8 = 1.44 liters of LN2

So over the 8 hour flight (assuming no fresh air circulation rate):

2.9 liters * 26 = 75 ft^3 of helium over 8 hours
1.4 liters * 25 = 35 ft^3 of nitrogen over 8 hours

Correct for 40,000 ft pressure in cabin (~4/3 Po) gives the following totals

100 ft^3 of liquid helium; 47 ft^3 of liquid nitrogen

The impact on cabin oxygen is .21 - .21*(147)/30,600 = 20.9 %

Assume now that you have the recircultion rate stated above at 5,400 cfm. The boil off rate per minute is .16 ft^3 helium and 0.08 ft^3 nitrogen, and this would quickly be flushed through the system.

Conclusion Standard operation quite safe for venting into the cabin.

1.2 Worst Case Analysis

The worst boil off rate could be as much as 60 liters of helium into the cabin in a matter of minutes. This could occur if there was a catastrophic failure of a window that allowed warm air to heat up the cryogen can causing helium to warm up and boil off very quickly. This case would boil off all the helium in a matter of minutes, and increase the boil off rate of the nitrogen. So we assume the following

60 liters of helium boil off in 60 seconds
60 liters of nitrogen boil off in 2 hours

1500 ft^3 LHe in one minute
1440 ft^3 LN2 over two hours = 12 in one minute

Oxygen depletion after correcting for pressure in the cabin after 1 minute is

.21 - .21* (2016/30,600) = 19.6 % still not a hazardous situation.

Further assume you have the recirculation rate mentioned above of 5,400 cfm. Then the 1500 ft^3 of helium should be flushed out in less than a minute.

Conclusion: Even in the worst case scenario, the immediate release of all the helium into the cabin will not impact safety of flight.